TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 727

A FLIGHT INVESTIGATION OF THE DISTRIBUTION OF ICE-INHIBITING FLUIDS ON A PROPELLER BLADE

By Lewis A. Rodert
Langley Memorial Aeronautical Laboratory

Washington
September 1939

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 727

A FLIGHT INVESTIGATION OF THE DISTRIBUTION OF ICE-INHIBITING FLUIDS ON A PROPELLER BLADE

By Lewis A. Rodert

SUMMARY

The flow of ice-inhibiting fluids over the blade surfaces of a 12.5-foot-diameter propeller was investigated in flight by discharging dyed fluids at various stations along the leading edges of the blades. The effects on the distribution of varying the fluid composition, the blade-surface roughness, and the orifice design were also observed.

The flow patterns obtained indicated that, under favorable combinations of type of fluid, surface smoothness, and orifice design, the fluid would flow from an orifice near the propeller hub along the leading edge to about the 40-inch blade station (53 percent of the blade radius). The fluid would not flow along the leading edge beyond the 40-inch station regardless of orifice location.

Fluids consisting of 85 percent alcohol and 15 percent of either glycerin or ethylene glycol flowed farthest along the leading edge. Decreasing the percentage of alcohol decreased the percentage of the blade length covered by the fluid. Discharging the fluid from an orifice that spread the fluid out in a thin film in intimate contact with the blade increased the blade coverage of a given volume of fluid. Surface roughness of the blade reduced the radial distribution.

INTRODUCTION

Current trends in airplane design indicate that higher air speeds, larger propeller diameters, and lower propeller angular velocities will be used in the near future. These changes are anticipated to affect adversely the problem of distributing ice-inhibiting fluid on the propeller blade and to render inadequate present protection against ice formation on propellers. A study has therefore been made of the problem of distributing ice-inhibiting fluid over the blade surfaces of a large-diameter propeller.

The flow patterns resulting from the emission of the fluids from orifices at various stations along the radius were observed. The effect on the distribution from the orifices along the blades resulting from the use of various fluids was studied during the tests to determine the importance of surface tension. Observations were also made of the effect on the fluid distribution of such factors as blade-surface roughness, orifice location with relation to the stagnation point, and orifice shape. Although adiabatic heating and centrifugal force may affect the accumulation of ice beyond a certain point on the blade radius, these factors were not considered in the present investigation.

The tests were conducted in flight at values of V/nD comparable with those of current transport airplanes. The speed of the airplane with which the flights were made was, however, lower than the cruising speeds currently used. The resultant data should apply qualitatively for the usual operating conditions for propellers of about the same diameter (12.5 feet) as the one tested.

APPARATUS AND FLUIDS

The tests of the distribution of ice-inhibiting fluids over the blade of a propeller were conducted at the N.A.C.A. laboratory at Langley Field, Va., on an Army XC-31 cargo airplane (fig. 1). This airplane was equipped with a 750-horsepower, radial, air-cooled engine geared to a three-blade, 12.5-foot-diameter propeller.

Figure 2 shows a close-up view of the hub assembly. Figure 3 shows the path followed by the fluid before leaving the orifice. Ice-inhibiting fluid was pumped to a distributing ring from which it was propelled by centrifugal force through distributor tubes to blade-root cups. The delivery from the distributor tubes to the root cup permits the blade angle to change without disrupting the flow of fluid. From the blade-root cups, the fluid is propelled again by centrifugal force through small tubes along the leading edge of each of the propeller blades to any desired blade station.

Some difficulty was experienced in obtaining a satisfactory flow of fluid through the distributing system. After the fluid entered the distributor ring, its continued motion was dependent entirely upon centrifugal force. The fluid therefore had to be provided with a path successive points of which were at increased radii. In order to insure that a large percentage of the fluid reached the orifices along the blades, it was found necessary to prevent the fluid from becoming air borne.

The tube running along the blade was a 0.05-inch-diameter stainless-steel tube with 0.005-inch wall thickness secured to the blade by wrapping both blade and tube with tape and applying airplane dope; the general appearance of the blade is shown in figure 4. The shrinkage of the doped fabric tape resulted in a tight and secure fastening of the tube to the blade.

At the start of the tests, the tubes at the leading edges of the blades terminated at the 57-inch station (76 percent of the blade radius). In order to locate orifices at blade-radius stations nearer the propeller hub, notches were cut through the tape at the leading edge and the tube was severed; from the resulting orifice, the liquid flowed over the tape-covered blade. Figure 4 shows such an orifice at a station near the propeller hub and the flow pattern of the fluid can be seen on the blade. Flow patterns were observed on the blades inboard of the orifice stations; they apparently were patterns of fluid that escaped from the distributing ring, became air borne, and collected on the propeller hub and the blade-root sections.

Early observations during the tests indicated that the flow pattern was affected by the surface roughness of the blade. For the later tests, the tape and the tubes were therefore removed from the blades over the region beyond the orifices and the blades were made as smooth as possible.

The chemicals used in the different fluids tested were 180 proof ethyl alcohol, U.S.P. glycerin, and a commercial grade of ethylene glycol. Most of the tests were made with a solution of 85 percent alcohol and 15 percent glycerin. This combination had been used by transport operators and found to possess satisfactory ice-inhibiting characteristics. Variations in viscosity and surface tension were obtained by using 100 percent glycerin and solutions of 50 percent alcohol and 50 percent glycerin, 50 percent alcohol and 50 percent ethylene glycol, and 85 percent alcohol and 15 percent ethylene glycol. Observations were made on the power of the various solutions to wet the blade surface, since the distribution over the surface is believed to be affected by the power of the fluid to dissolve or to combine with the oil film covering most propellers. The fluids were dyed by the addition of methylene blue. The distribution patterns were retained after the flights by the deposits of dye that remained on the blades. Records of the patterns were preserved by pressing onto the blade surface a sheet of tracing paper to which the dye adhered.

RESULTS AND DISCUSSION

The patterns of the flow from orifices at various blade-radius stations over the flat and the cambered faces of the propeller for the most favorable conditions are shown in figure 5. The flow along the blade leading edge is of greater importance in the prevention of ice accretion than is the flow over the blade faces. When the various factors that influenced the flow along the leading edge were most favorable, it was possible to make the fluid flow out to about the 40-inch blade station (53 percent of the blade radius) from orifices located near the propeller hub. Flow beyond the end of the tube along the leading edge beyond the 40-inch blade station, however, could not be produced regardless of the orifice location. At the outer blade stations, the leading-edge radius becomes small and the air speed is great, both of which features tend to reduce the region of low velocity in the vicinity of the stagnation pressure line. These two factors are believed to limit and finally to stop the flow to the outer blade stations.

The flow distribution is thought to be affected to some degree by the presence of the cowling for the radial engine. The shape and the position of the cowling will influence the air flow over the inner blade stations and therefore will affect the fluid movement on the blades.

The best fluid distribution was obtained with solutions of 85 percent alcohol and 15 percent of either glycerin or ethylene glycol. Solutions having greater percentages of either glycerin or ethylene glycol were blown back chordwise more readily than the optimum mixture. A decrease in the percentage of alcohol increased the surface tension and decreased the wetting power of the fluid, both of which reduced the fluid travel along the blade. A change of viscosity apparently does not change the flow pattern over the propeller blade, because the flow of lubricating oil that leaked out from the propeller hub gave about the same pattern as did the much less viscous alcohol-glycerin solutions. The flow patterns obtained using ethylene glycol did not differ from those obtained when the same percentage of glycerin was used. This result will be noted by a comparison of the flow patterns shown in figure 6 (a) and 6 (b).

Observations made of the effect of surface roughness on the fluid distribution showed that roughness along the leading edge decreased the amount of fluid which would flow radially past a given point and therefore reduced the percentage of blade radius covered. Roughness on the face of a blade caused the fluid to be swept toward the trailing edge at a sharper angle. Apparently the best fluid distribution along the blade was obtained where laminar flow existed. Figure 5 shows that a sharp break occurred in the flow lines on the cambered face of the blade when the orifice was located at the 27-inch blade station. This break in the lines was probably due to a transition from laminar to turbulent flow.

The volume of fluid that could be delivered to any point on the blade beyond the orifice was dependent to a considerable extent upon the shape of the orifice. It was found that, when the fluid was released slightly under the edge of the tape which bound the tubes to the blade (fig. 7), the delivery was improved because the fluid then made contact with the blade over a considerable width. Releasing a thin film of fluid in direct contact with the blade seemed to reduce the amount of fluid that was immediately blown away. In order to obtain flow along the leading edge, locating the orifice exactly at the point of stagnation pressure was necessary.

According to these results, the prevention of ice on large propellers will require a distribution system that will supply fluid at continuous points along the leading edge independent of the blade radius. At the outer blade stations, this requirement may necessitate a system of internal ducts opening along the leading edge or of channels along the leading edge.

CONCLUSIONS

1. An ice-inhibiting fluid was observed to flow along the leading-edge surface of the propeller blade to about the 40-inch station (53 percent of the blade radius) when discharged from an orifice located at various points between the propeller hub and the 40-inch station. The fluid would not flow along the leading edge beyond the 40-inch station, regardless of the orifice location.

2. The most favorable conditions for extensive distribution of fluid along a propeller blade were obtained by using a solution of 85 percent alcohol and 15 percent of either glycerin or ethylene glycol, which was discharged in a thin film in intimate contact with a smooth blade surface along the line of stagnation pressures.

National Advisory Committee for Aeronautics,
Langley Memorial Aeronautical Laboratory,
Langley Field, Va., July 28, 1939.

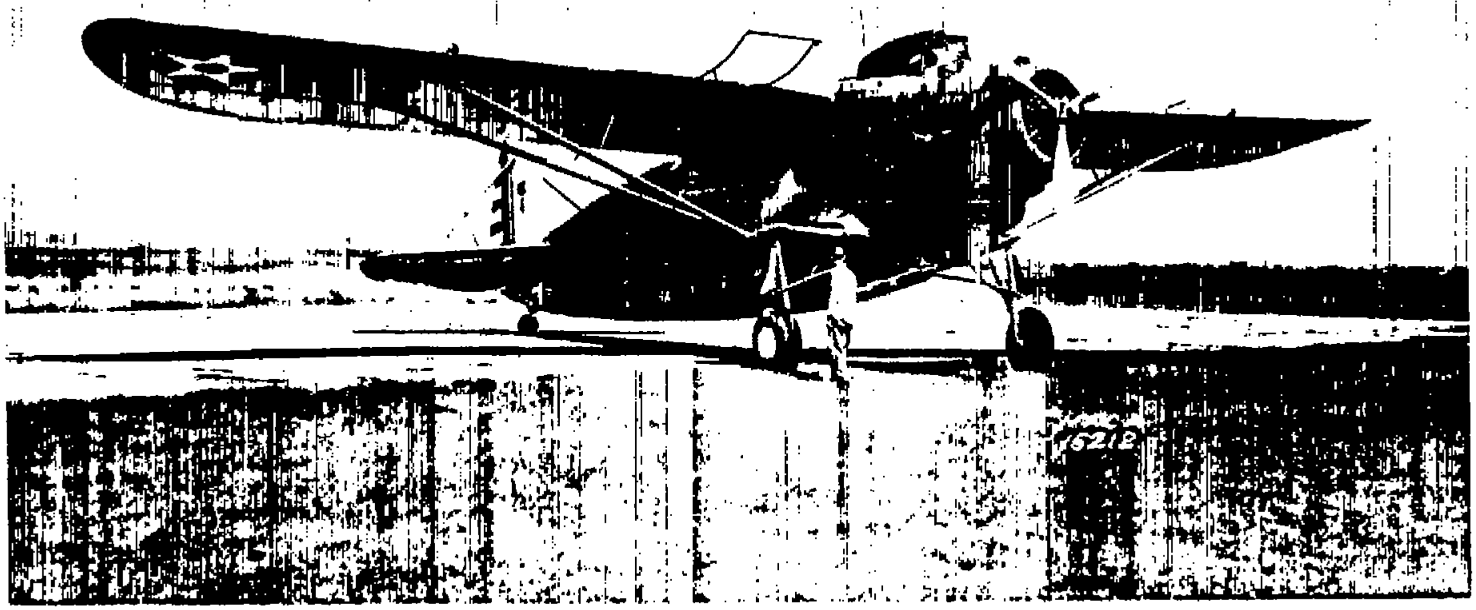


Figure 1.- The XC-31 Army cargo airplane.

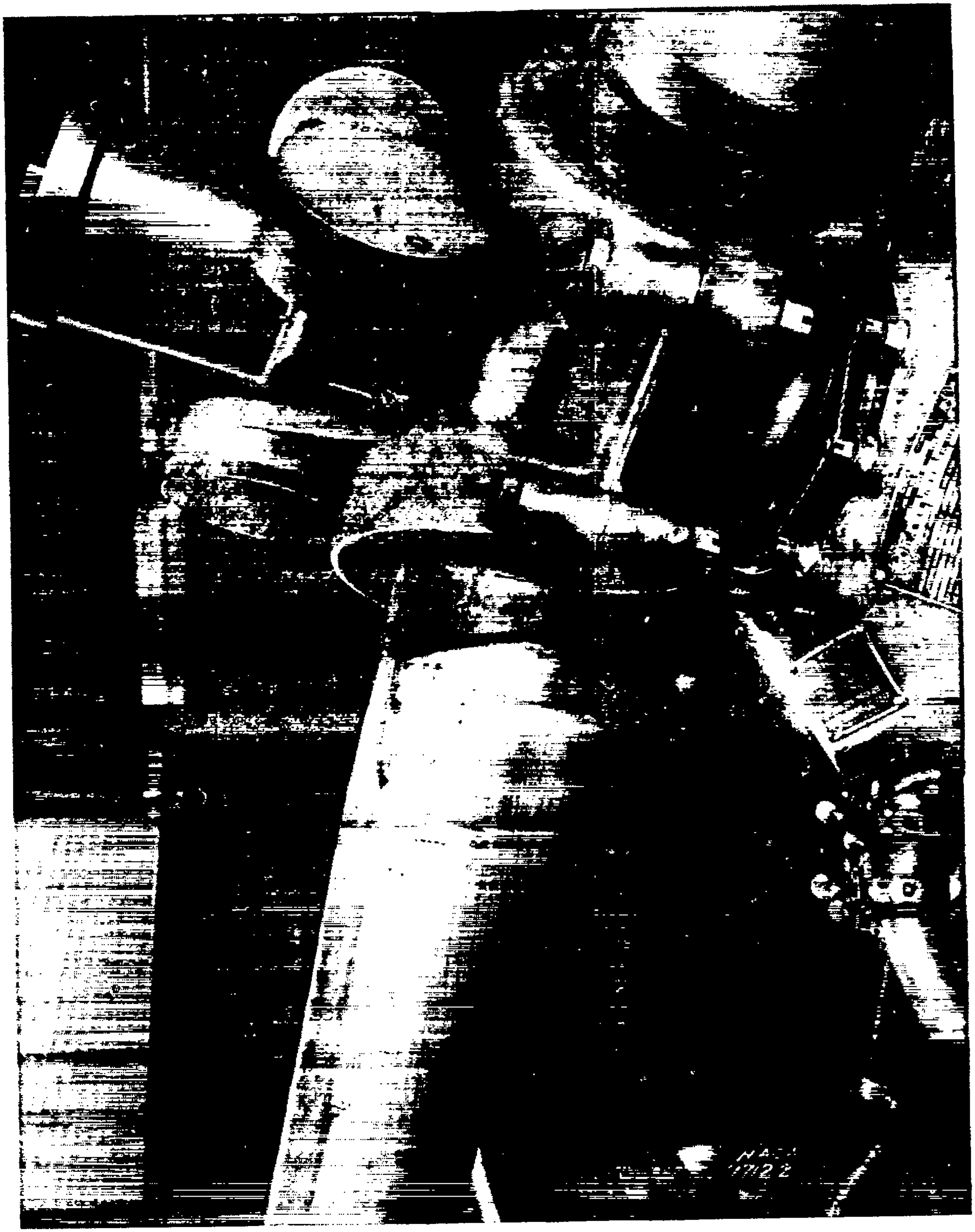


Figure 2.- The propeller hub showing the fluid-distributing system.

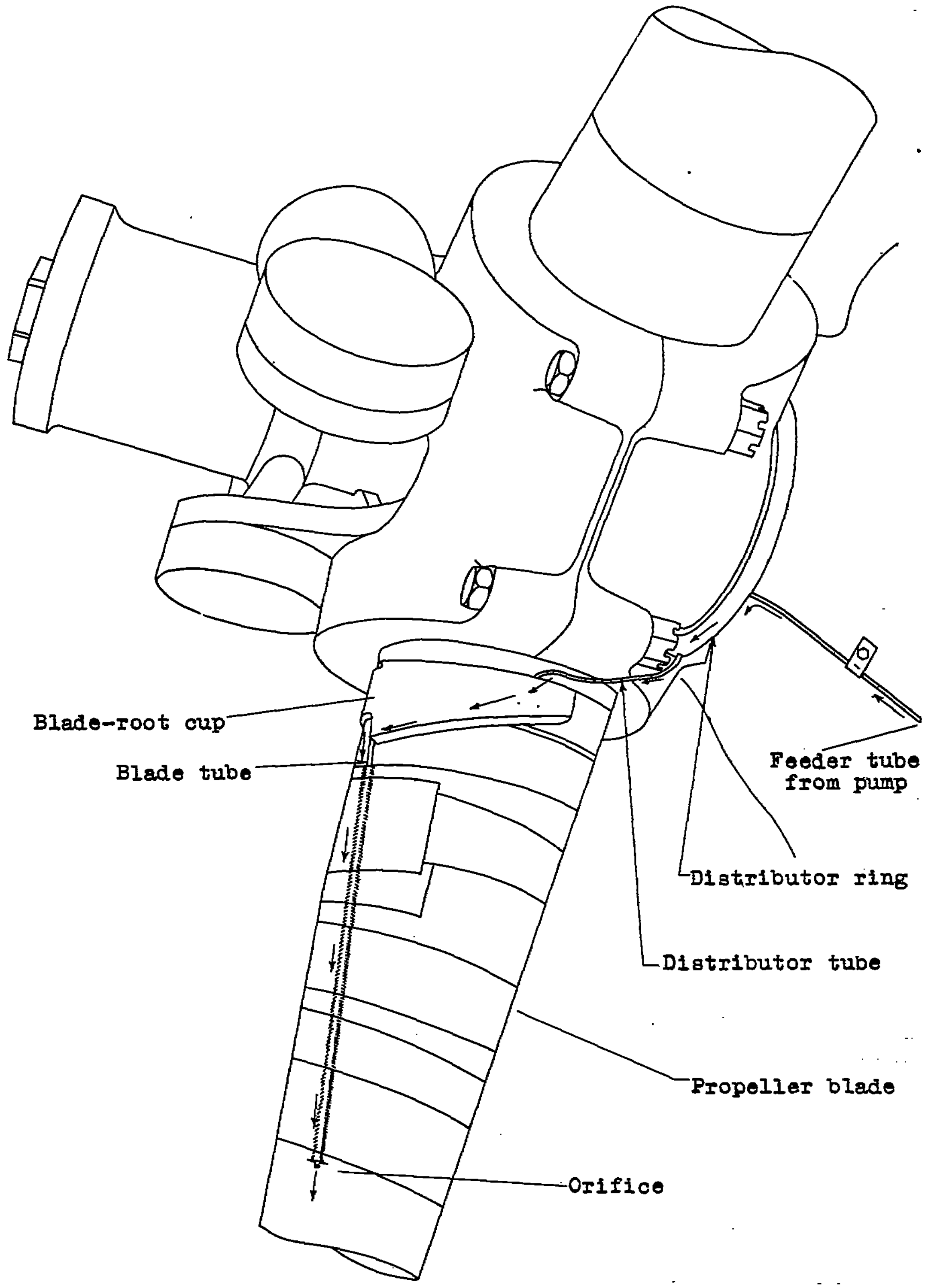


Figure 3.- Diagram showing path of ice-inhibiting fluid before leaving orifice.

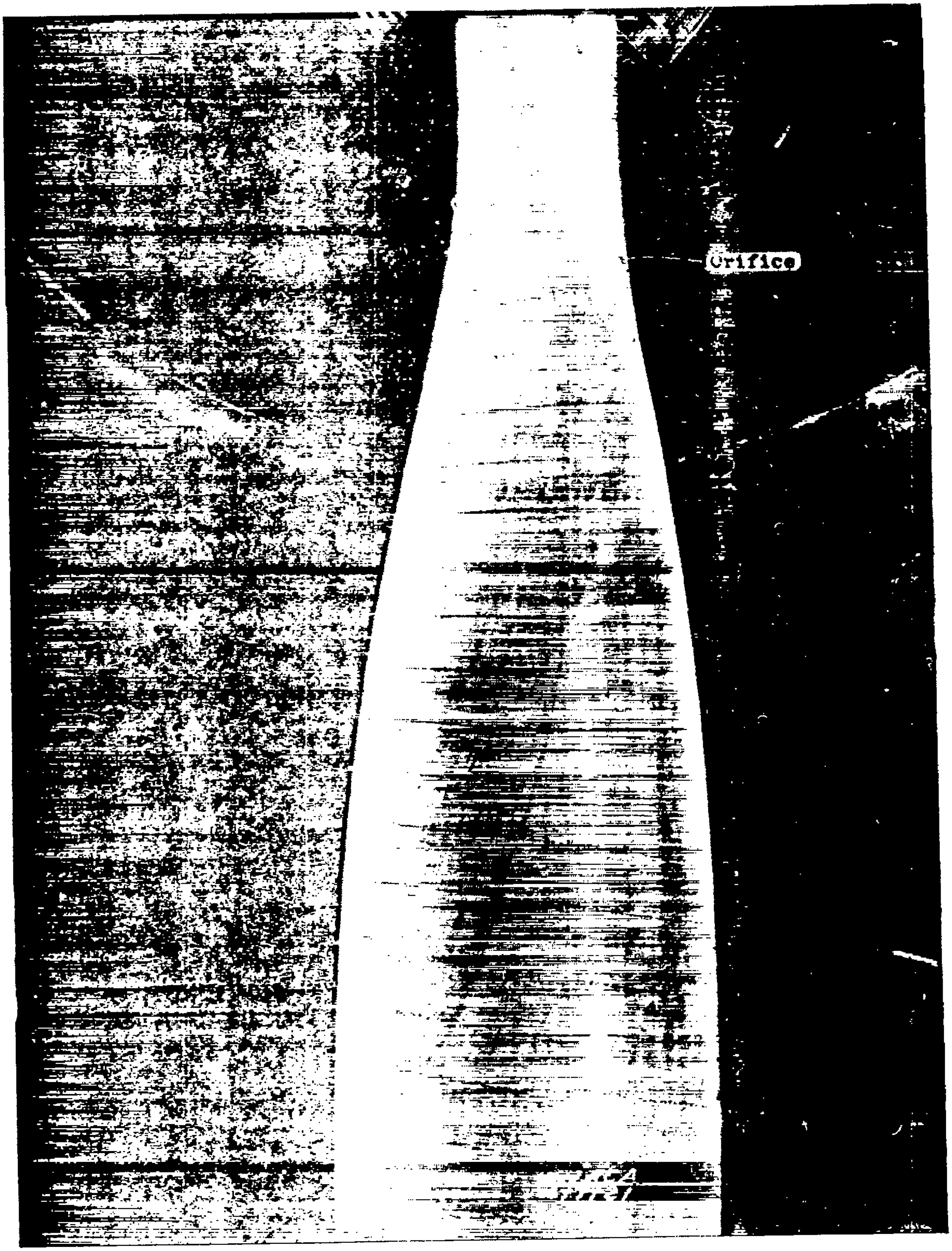


Figure 4.- A view of a blade with a distributing tube attached to the leading edge. The flow pattern on the face of the blade, resulting from fluid emitted from an orifice near the hub can be seen.

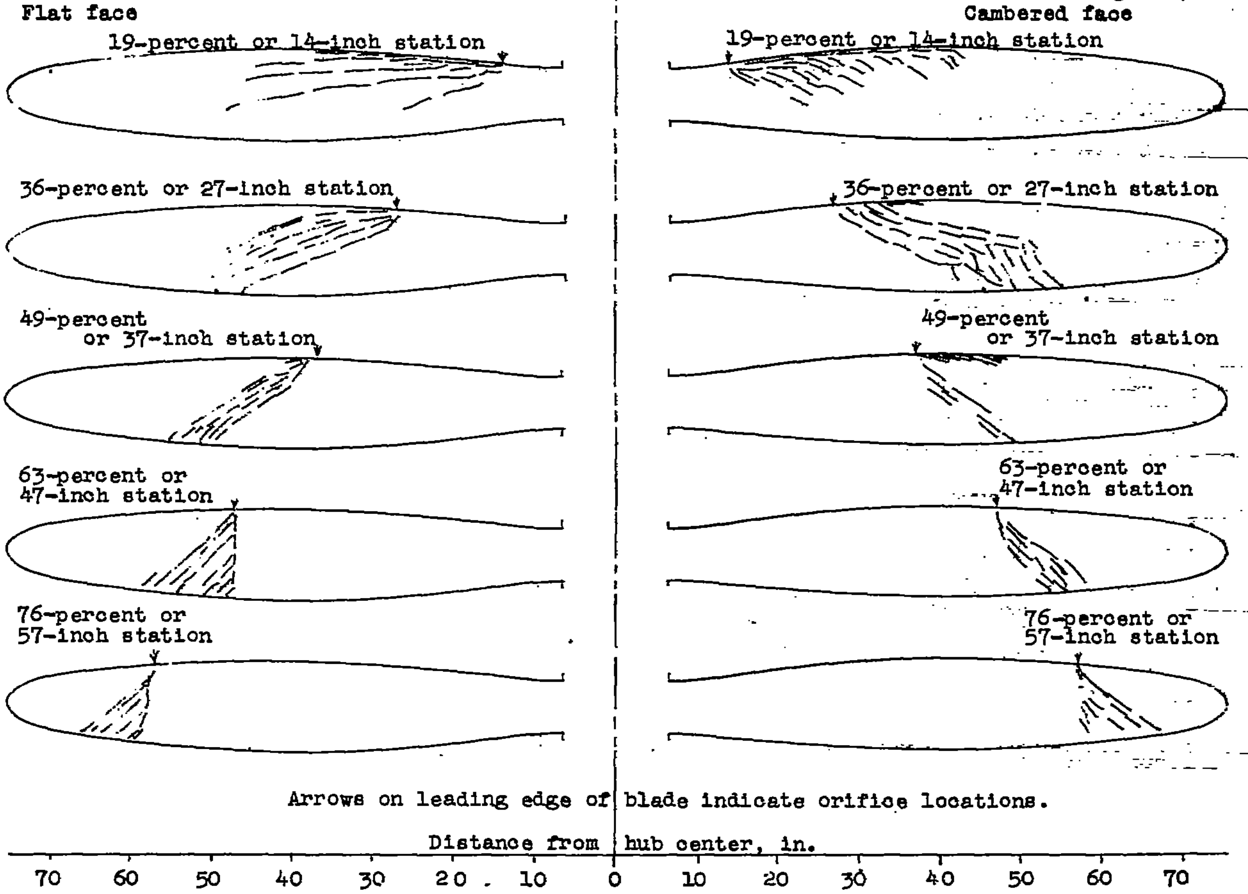
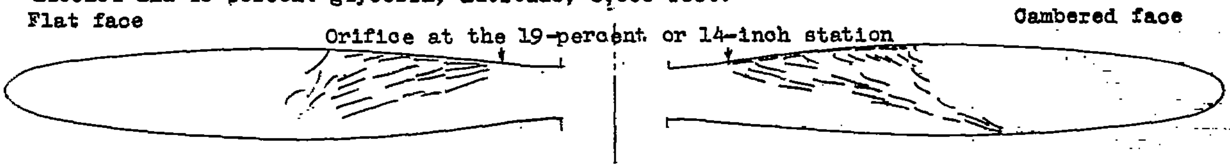
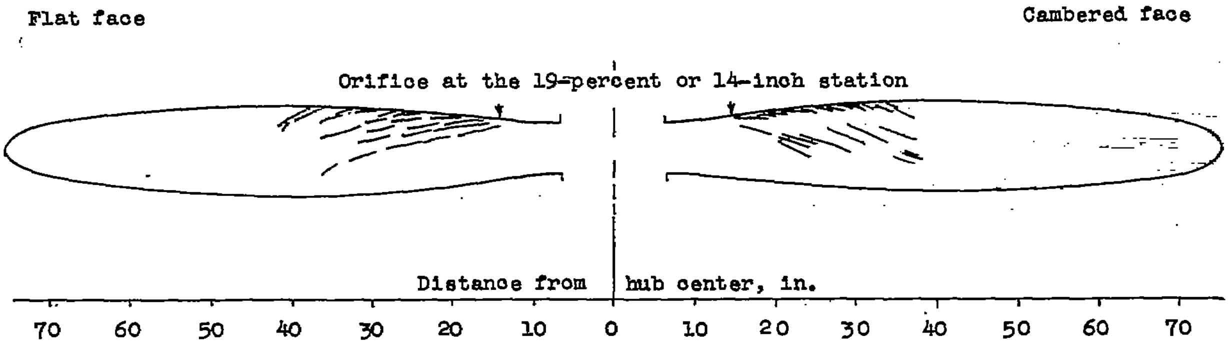


Figure 5.-Fluid distribution over flat and cambered faces of blade of 12.5-foot-diameter propeller. Air speed, 125 miles per hour, V/nd, 0.89, fluid, 85 percent alcohol and 15 percent glycerin, altitude, 6,000 feet.



(a) Fluid, 50 percent alcohol and 50 percent ethylene glycol.



(b) Fluid, 50 percent alcohol and 50 percent glycerin.

Figure 6.- Fluid distribution over flat and cambered faces of blade of 12.5-foot-diameter propeller. Air speed, 125 miles per hour, V/nD, 0.89, altitude, 6,000 feet.

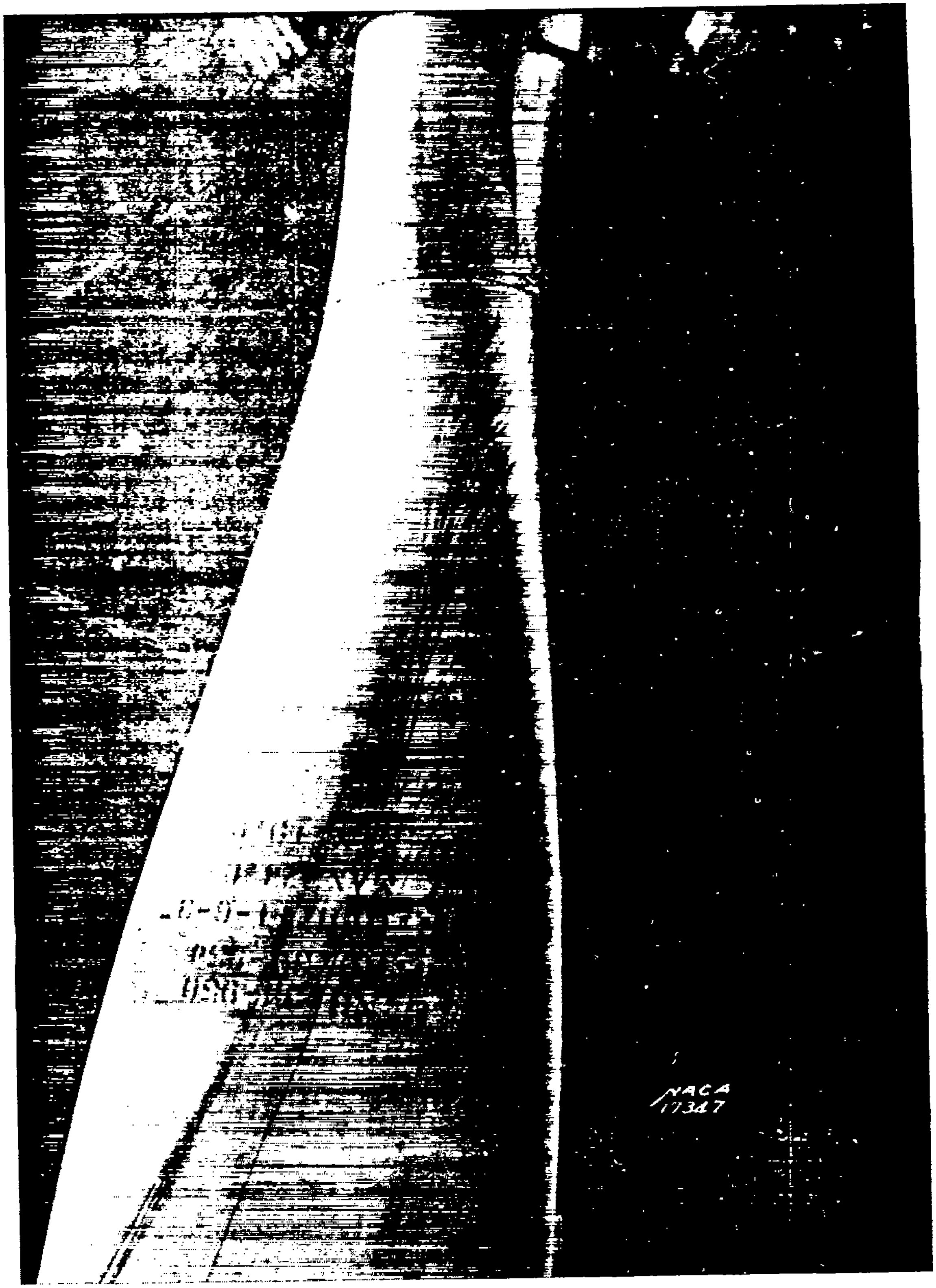


Figure 7.- Orifice located near the propeller hub(14-inch station). The fluid is discharged from the tube under the tape. Fluid from this orifice traveled along the leading edge of the blade to slightly beyond the 40-inch blade station.